



Cognition · Affect · Action

Institut für Psychologie
Lehrstuhl Allgemeine Psychologie II

Substantive Research Questions and Psychological Theory

Multinomial Modeling of the Implicit Association Test (IAT)

Franziska Meissner

DGPs Conference 2018 | Workshop on MPT Modeling
Erdfelder, Heck, & Meissner
Frankfurt, September 15, 2018



FRIEDRICH-SCHILLER-
UNIVERSITÄT
JENA

Agenda

1. The Implicit Association Test (IAT)
2. MPT modeling of the IAT: The ReAL model
 - 2.1 Model development
 - 2.2 Model validation
 - 2.3 Model application
3. Different models for different research questions
4. Discussion





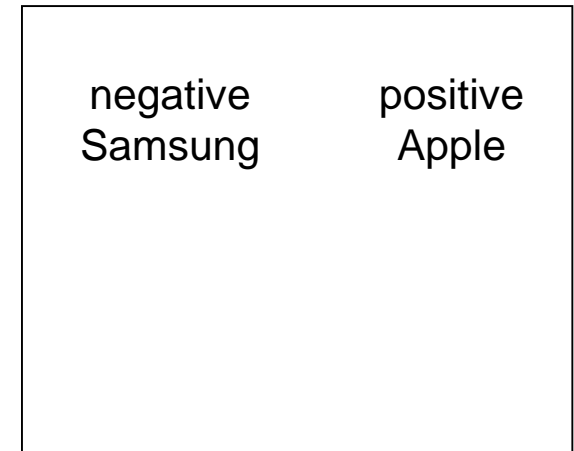
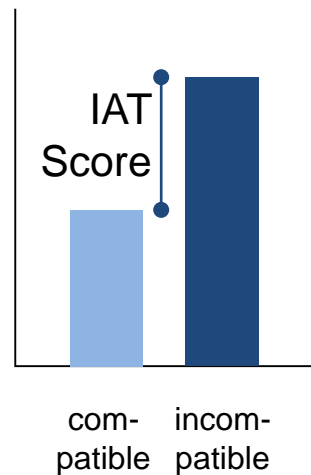
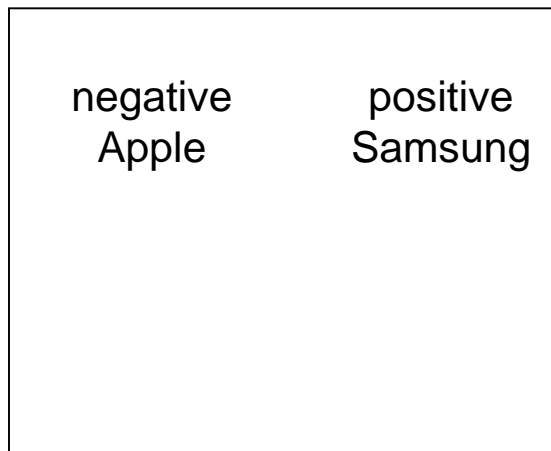
1. The Implicit Association Test (IAT)



The Implicit Association Test (IAT)

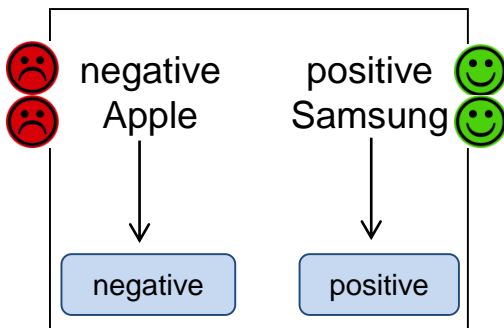
(Greenwald, McGhee, & Schwartz, 1998)

Compatible Block

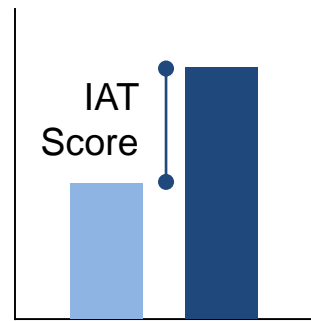


Problem 1: Recoding

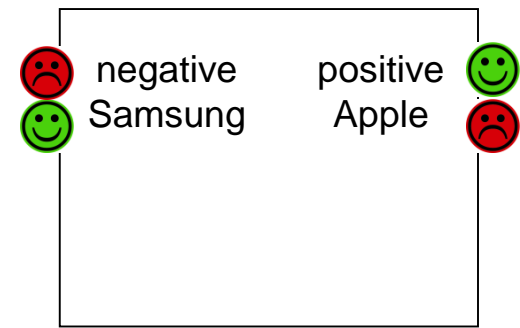
Compatible Block



→ simplified task



Incompatible Block



→ no simplification



Samsung:



Apple:

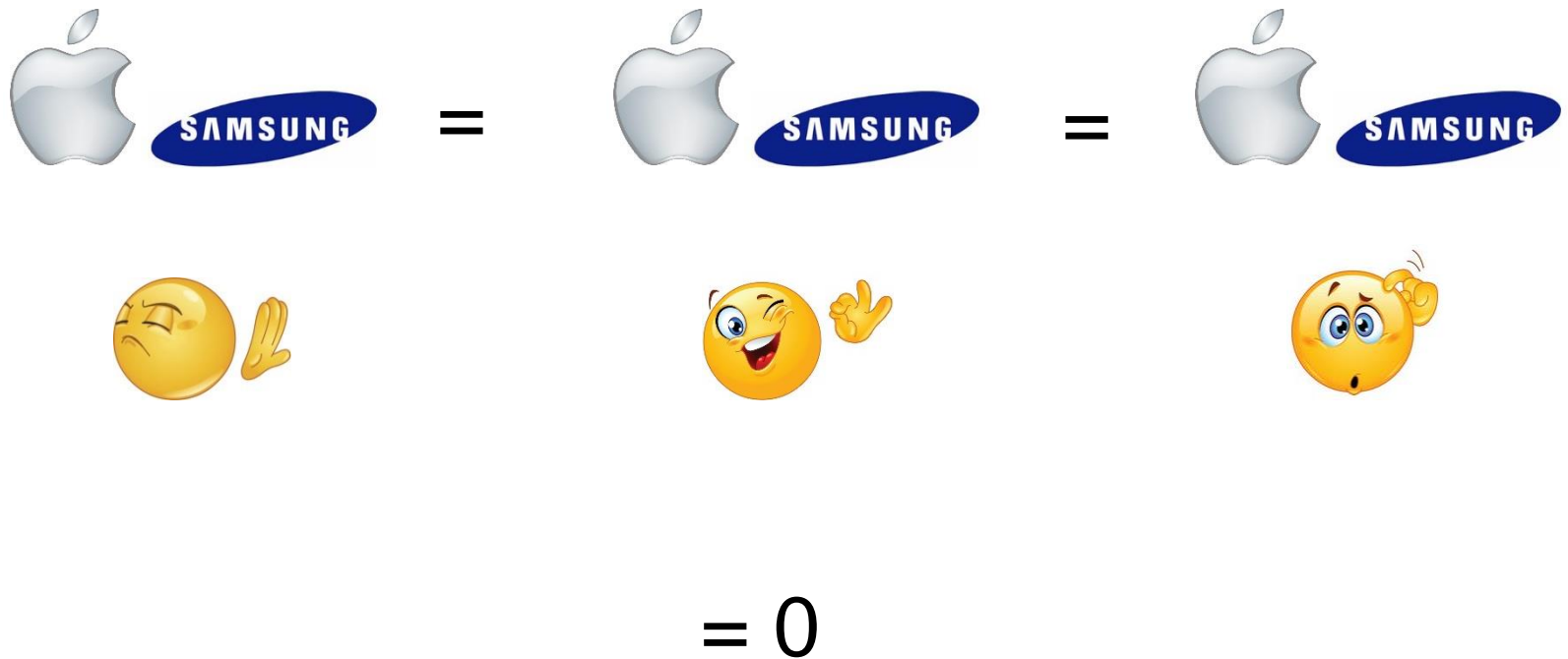


positive: peace, love, vacation



negative: war, murder, bomb

Problem 2: Preference Score



2. MPT Modeling of the IAT: The ReAL Model



Introducing ~~the ReAL~~ Model: 3 Steps

any new MPT



2.1 **Developing** the model



2.2 **Validating** the model



2.3 **Applying** the model to examine open questions



2.1 Model Development

- Response categories
- Model parameters
- Tree structure



Response Categories

	compatible block		incompatible block	
	correct	incorrect	correct	incorrect
Samsung				
Apple				
positive				
negative				

task repetition

	compatible block		incompatible block	
	correct	incorrect	correct	incorrect
Samsung				
Apple				
positive				
negative				

task switch



16 non-redundant response categories
(because $n_{\text{errors}} = n_{\text{total}} - n_{\text{correct}}$)



Model Parameters



(Meissner & Rothermund, 2013)

Recoding *Re*

Associations



Label-based identification of the response

L_1 
 L_2 
 L_3 positive
 L_4 negative



Tree Structure

(Meissner & Rothermund, 2013)

- Incorporates theoretical assumptions regarding the processes, e.g.:
- **Recoding** determines responding...
(e.g., Mierke & Klauer, 2001; Rothermund, Teige-Mocigemba, Gast, & Wentura, 2009)
 - in both target and attribute trials
 - only in the compatible block
- **Associations** determine responding...
(e.g., Anderson, 1983; Fazio, Sanbonmatsu, Powell, & Kardes, 1986)
 - only in target trials
 - in both compatible and incompatible blocks



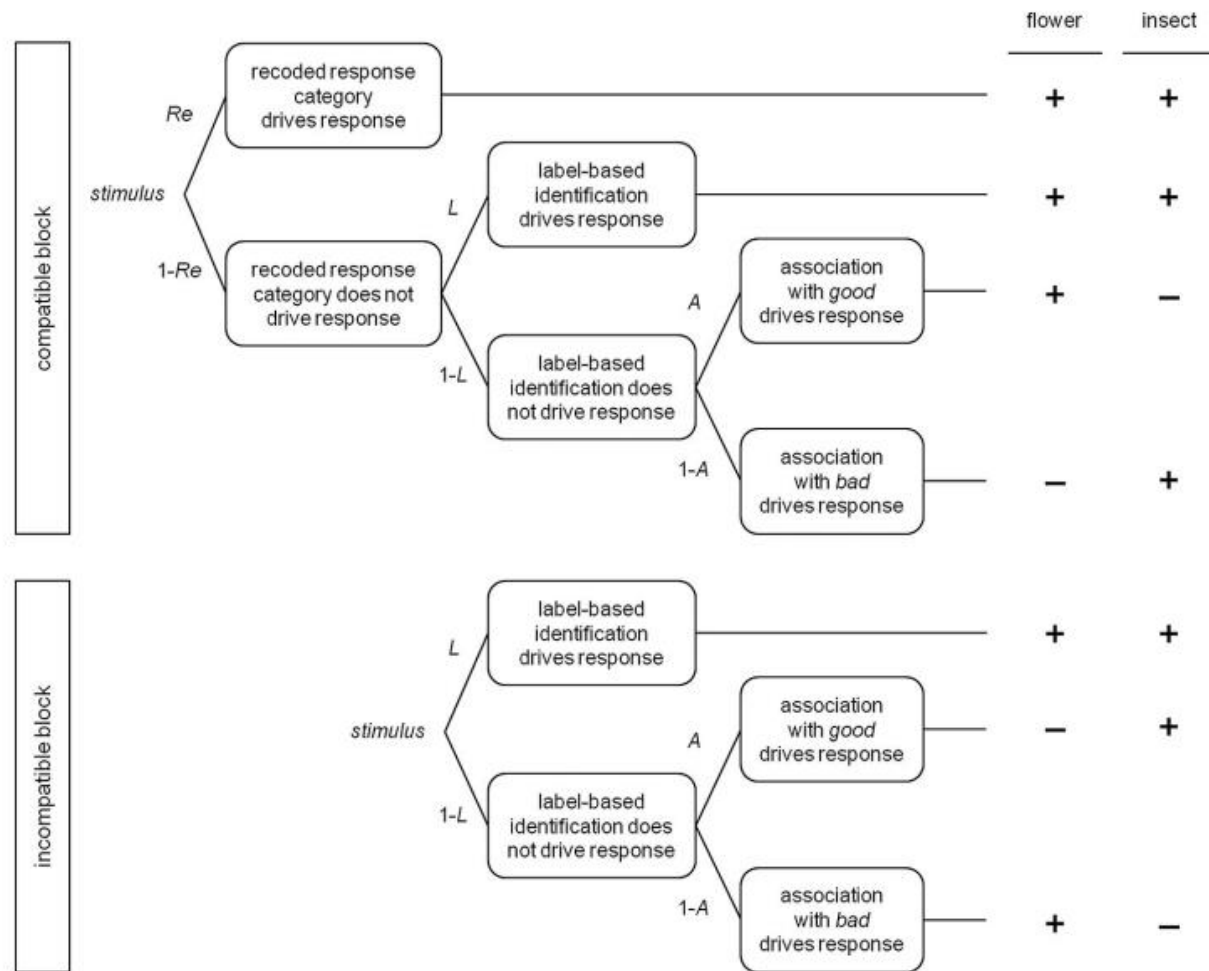


Figure 1. The ReAL model for the Implicit Association Test (IAT) for exemplars of the categories *flower* and *insect* in a flower–insect IAT. The figure illustrates an overview over the postulated interplay of recoding processes (*Re*), evaluative associations (*A*), and the label-based identification of the correct response (*L*). Dependent on the block (compatible, incompatible), a certain combination of model parameters predicts either a correct (+) or an incorrect (-) response.

Model Equations

1	1	Re*attReC*attReT	7	13	Re*attReT	12	23	L2*attL
1	1	Re*attReC*(1-attReT)*L1	7	13	Re*(1-attReT)*L4	12	23	L2*(1-attL)*A2
1	1	Re*attReC*(1-attReT)*(1-L1)*A1	7	14	Re*(1-attReT)*(1-L4)*A4	12	24	L2*(1-attL)*(1-A2)
1	2	Re*attReC*(1-attReT)*(1-L1)*(1-A1)	7	13	Re*(1-attReT)*(1-L4)*(1-A4)	12	23	(1-L2)*A2
1	1	Re*(1-attReC)*L1	7	13	(1-Re)*L4	12	24	(1-L2)*(1-A2)
1	1	Re*(1-attReC)*(1-L1)*A1	7	14	(1-Re)*(1-L4)*A4	13	25	Re
1	2	Re*(1-attReC)*(1-L1)*(1-A1)	7	13	(1-Re)*(1-L4)*(1-A4)	13	25	(1-Re)*L3*attL
1	1	(1-Re)*L1	8	15	L4	13	25	(1-Re)*L3*(1-attL)*A3
1	1	(1-Re)*(1-L1)*A1	8	15	(1-L4)*A4	13	26	(1-Re)*L3*(1-attL)*(1-A3)
1	2	(1-Re)*(1-L1)*(1-A1)	8	16	(1-L4)*(1-A4)	13	25	(1-Re)*(1-L3)*A3
2	3	L1	9	17	Re*attReC	13	26	(1-Re)*(1-L3)*(1-A3)
2	4	(1-L1)*A1	9	17	Re*(1-attReC)*L1*attL	14	27	L3*attL
2	3	(1-L1)*(1-A1)	9	17	Re*(1-attReC)*L1*(1-attL)*A1	14	28	L3*(1-attL)*A3
3	5	Re*attReC*attReT	9	18	Re*(1-attReC)*L1*(1-attL)*(1-A1)	14	27	L3*(1-attL)*(1-A3)
3	5	Re*attReC*(1-attReT)*L2	9	17	Re*(1-attReC)*(1-L1)*A1	14	28	(1-L3)*A3
3	6	Re*attReC*(1-attReT)*(1-L2)*A2	9	18	Re*(1-attReC)*(1-L1)*(1-A1)	14	27	(1-L3)*(1-A3)
3	5	Re*attReC*(1-attReT)*(1-L2)*(1-A2)	9	17	(1-Re)*L1*attL	15	29	Re
3	5	Re*(1-attReC)*L2	9	17	(1-Re)*L1*(1-attL)*A1	15	29	(1-Re)*L4*attL
3	6	Re*(1-attReC)*(1-L2)*A2	9	18	(1-Re)*L1*(1-attL)*(1-A1)	15	30	(1-Re)*L4*(1-attL)*A4
3	5	Re*(1-attReC)*(1-L2)*(1-A2)	9	17	(1-Re)*(1-L1)*A1	15	29	(1-Re)*L4*(1-attL)*(1-A4)
3	5	(1-Re)*L2	9	18	(1-Re)*(1-L1)*(1-A1)	15	30	(1-Re)*(1-L4)*A4
3	6	(1-Re)*(1-L2)*A2	10	19	L1*attL	15	29	(1-Re)*(1-L4)*(1-A4)
3	5	(1-Re)*(1-L2)*(1-A2)	10	20	L1*(1-attL)*A1	16	31	L4*attL
4	7	L2	10	19	L1*(1-attL)*(1-A1)	16	31	L4*(1-attL)*A4
4	7	(1-L2)*A2	10	20	(1-L1)*A1	16	32	L4*(1-attL)*(1-A4)
4	8	(1-L2)*(1-A2)	10	19	(1-L1)*(1-A1)	16	31	(1-L4)*A4
5	9	Re*attReT	11	21	Re*attReC	16	32	(1-L4)*(1-A4)
5	9	Re*(1-attReT)*L3	11	21	Re*(1-attReC)*L2*attL			
5	9	Re*(1-attReT)*(1-L3)*A3	11	22	Re*(1-attReC)*L2*(1-attL)*A2			
5	10	Re*(1-attReT)*(1-L3)*(1-A3)	11	21	Re*(1-attReC)*L2*(1-attL)*(1-A2)			
5	9	(1-Re)*L3	11	22	Re*(1-attReC)*(1-L2)*A2			
5	9	(1-Re)*(1-L3)*A3	11	21	Re*(1-attReC)*(1-L2)*(1-A2)			
5	10	(1-Re)*(1-L3)*(1-A3)	11	21	(1-Re)*L2*attL			
6	11	L3	11	22	(1-Re)*L2*(1-attL)*A2			
6	12	(1-L3)*A3	11	21	(1-Re)*L2*(1-attL)*(1-A2)			
6	11	(1-L3)*(1-A3)	11	22	(1-Re)*(1-L2)*A2			
			11	21	(1-Re)*(1-L2)*(1-A2)			

ReAL model eqn file

The ReAL model for the IAT

(Meissner & Rothermund, 2013)




- | | | Test against |
|------------------------------|--------------------------|--------------|
| • 7 core parameters | | |
| – recoding | (Re) | 0 |
| – associations | (A_1, A_2) | .5 |
| – label-based discrimination | (L_1, L_2, L_3, L_4) | 0 |
| • 3 technical parameters | $(attL, attReC, attReT)$ | |

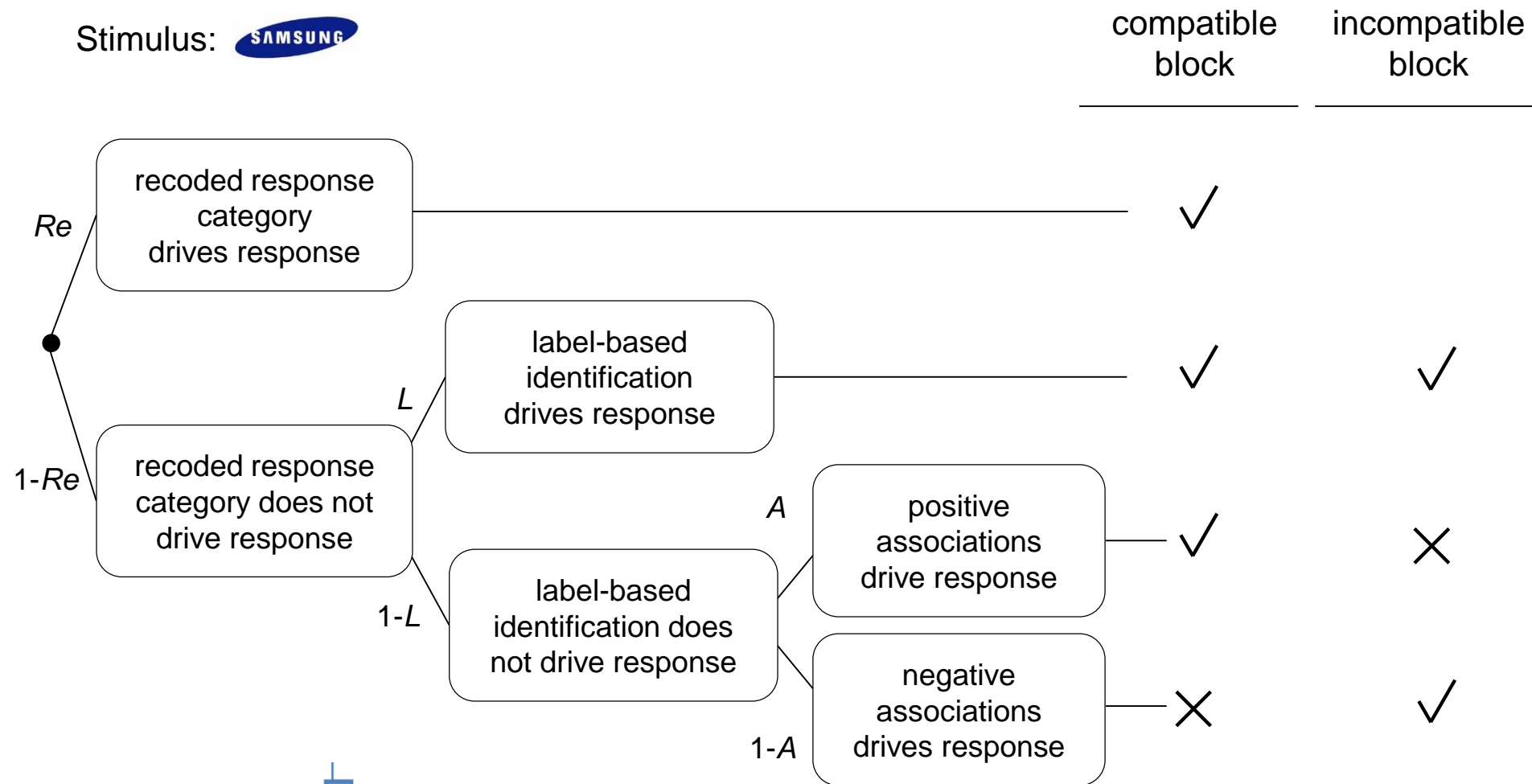
➡ 10 parameters

➡ 16 independent response categories
i.e., $df = 6$ for model fit test



Tree Structure (simplified)

Stimulus: 



Pilot Study: Flower-Insect IAT

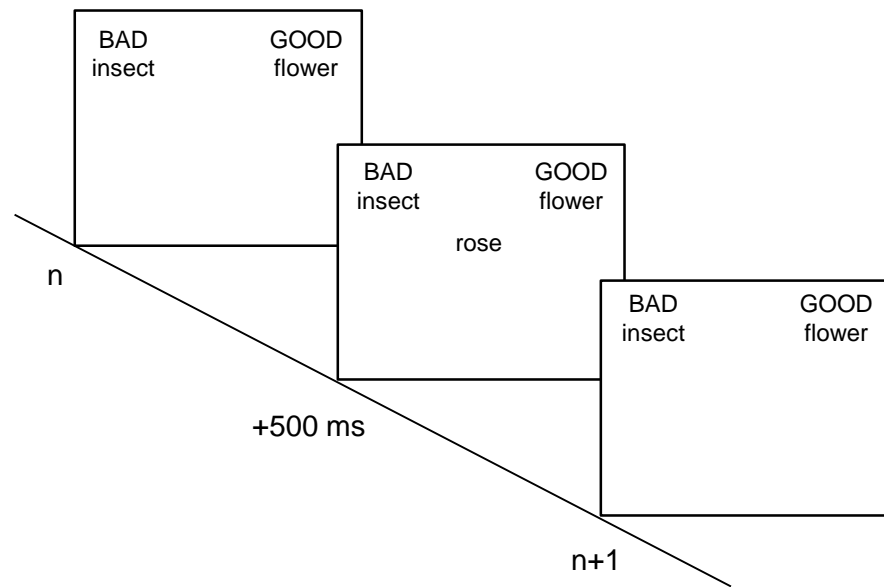
- Targets: **flower** (e.g., “rose”, “tulip”) vs. **insect** (e.g., “maggot”, “wasp”)
- Attributes: **good** (e.g., “holiday”, “peace”) vs. **bad** (e.g., “fear”, “pain”)
- 160 trials per participant
- $N = 18$

Model Fit?

Re , A & L sign.?

$A_{\text{flower}} > .5?$

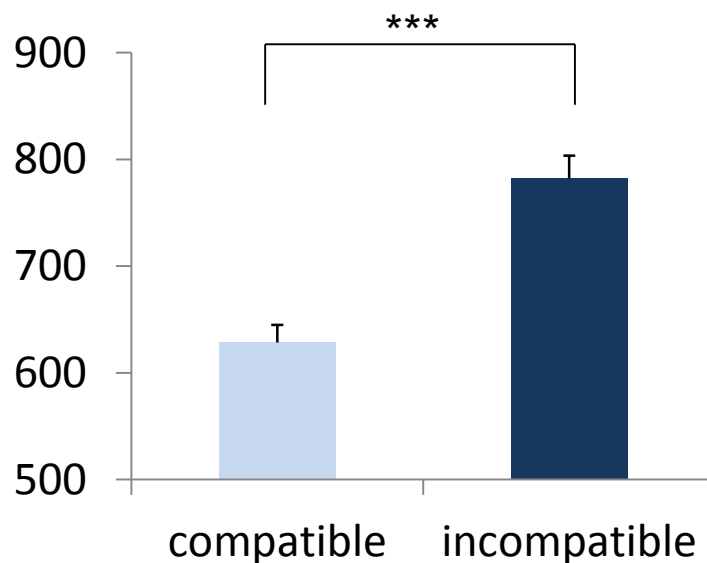
$A_{\text{insect}} < .5?$



Pilot Study: Flower-Insect IAT

< 8% errors

Analysis of RTs



Strong RT effects

Model analysis

(complete pooling)

Parameter	Estimate	95% CI
L_{flower}	.86***	[.80, .93]
L_{insect}	.84***	[.77, .91]
L_{good}	.91***	[.86, .96]
L_{bad}	.84***	[.78, .90]
Re	.34*	[.09, .60]
A_{flower}	.60	[.40, .79]
A_{insect}	.37 [†]	[.18, .56]

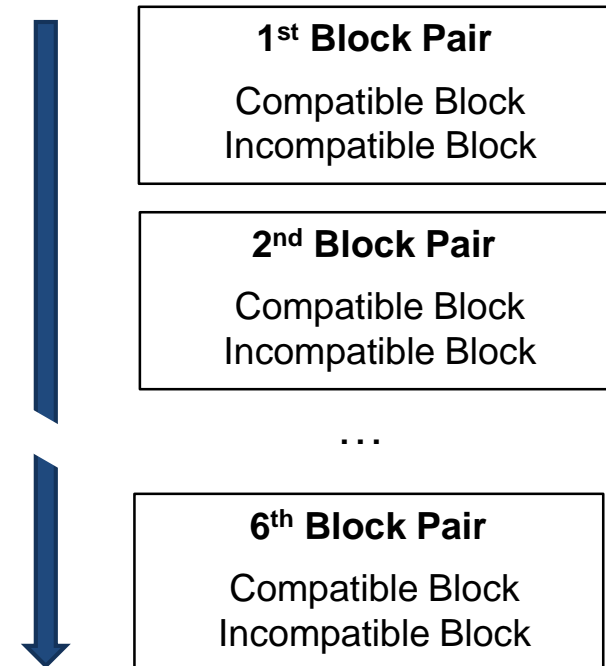
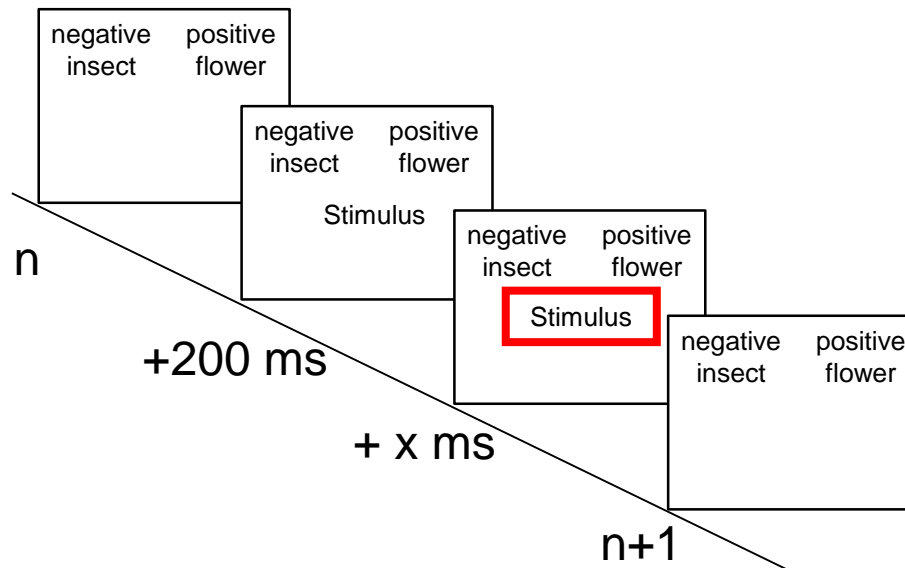
≠[†]

Note: $G^2(6) = 6.00$, $p = .423$

[†] $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$.



Transferring RT effects into error rates



ReAL IAT Procedure

- response deadline
- more trials (i.e., more blocks): 320 trials per participant
 ↳ individual estimates

2.2 Model Validation



Model Validation

- It is **not sufficient**...
 - ...to come up with a model structure
 - ...to label parameters according to some important processes
 - ...and to check model fit.
- Additionally, test whether the parameters are **valid** measures of those processes.
 - Make use of **established** manipulations. You should be as sure as possible that these manipulations tap into one and only one process.
 - Do so **before** applying the model to new research questions.
 - Be patient.

„Validating the process parameters typically requires a careful and costly experimental program in which convergent and discriminant validity are established for each parameter“ (Klauer, Stahl, & Voss, 2012)



Model Validation

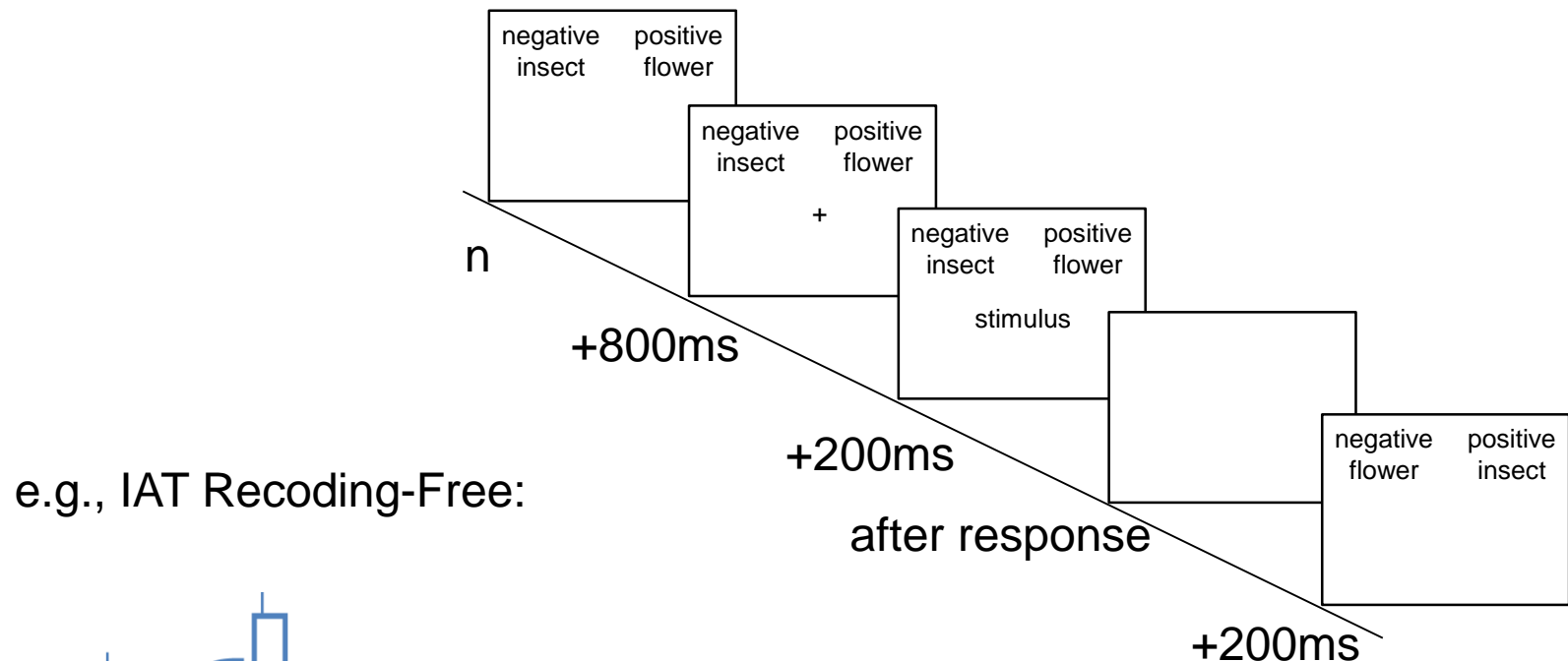
- For the ReAL model, we did 7 validation studies.
- Selective influence studies
Experimental manipulations addressing a specific process should affect only parameters reflecting this process.
 - Study 1 (*Re*)
 - Study 2 (*A*)
- Correlative studies
Parameters should be valid measures of inter-individual differences.
 - Study 3 (convergent validity of *A*)
 - Study 4 (predictive validity of *A*)



Study 1: Manipulating Recoding

(Meissner & Rothermund, 2013)

- **Recoding is reduced** if block structure is dropped
 - IAT Recoding-Free (Rothermund, Teige-Mocigemba, Gast, & Wentura, 2009)
 - Single-Block IAT (Teige-Mocigemba, Klauer, & Rothermund, 2008)



Study 1: Manipulating Recoding

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 - IAT Recoding-Free (Rothermund, Teige-Mocigemba, Gast, & Wentura, 2009)
 - Single-Block IAT (Teige-Mocigemba, Klauer, & Rothermund, 2008)
- Experimental manipulation of *Re*
 - Control group: Standard IAT ($N = 40$)
 - Experimental group: IAT-RF or SB-IAT ($N = 80$)

(Flower-insect IAT with response deadline)



Study 1: Manipulating Recoding

(Meissner & Rothermund, 2013)

Control Group

Parameter	Mean Estimate	SE
<i>Re</i>	.46***	.04
<i>A</i> _{flower}	.64***	.03
<i>A</i> _{insect}	.38***	.03
<i>L</i> _{flower}	.58***	.03
<i>L</i> _{insect}	.54***	.03
<i>L</i> _{good}	.64***	.03
<i>L</i> _{bad}	.65***	.03

Note: median $G^2(6) = 8.90$, $p = .179$

Experimental Group

Parameter	Mean Estimate	SE
<i>Re</i>	.30***	.02
<i>A</i> _{flower}	.60***	.02
<i>A</i> _{insect}	.40***	.02
<i>L</i> _{flower}	.38***	.02
<i>L</i> _{insect}	.37***	.02
<i>L</i> _{good}	.65***	.02
<i>L</i> _{bad}	.70***	.02

Note: median $G^2(6) = 7.47$, $p = .280$

† $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$.

Study 2: Manipulating Associations

(Meissner & Rothermund, 2013)

- **Associations can be formed** by a short story providing positive/negative information about unknown groups (e.g., Gregg, Seibt, & Banaji, 2006)
- Experimental manipulation of A
 - Faked article about **two fictive soccer teams**: „Blauheim“ and „Rundstedt“
 - Described clearly positive vs. negative (counterbalanced, i.e., Blauheim=positive & Rundstedt=negative, or vice versa)
 - Afterwards, Blauheim-Rundstedt IAT (with response deadline)
 - $N = 40$



Study 2: Manipulating Associations

(Meissner & Rothermund, 2013)

	Parameter	Mean Estimate	SE
	<i>Re</i>	.36*	.04
≠***	<i>A</i> _{positiveTeam}	.48	.02
	<i>A</i> _{negativeTeam}	.39***	.02
	<i>L</i> _{positiveTeam}	.32***	.03
	<i>L</i> _{negativeTeam}	.41***	.03
	<i>L</i> _{good}	.70***	.03
	<i>L</i> _{bad}	.64***	.03

Note: median $G^2(6) = 7.90$, $p = .246$

† $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$.



Study 3: Convergent Validity

(Meissner & Rothermund, unpublished)

- $N = 65$
- Self-esteem IAT
 - self vs. favorite other
 - idiographic stimuli
- Criterion: Name Letter Task (NLT)

negative	positive
Jane Doe	John Doe

negative	positive
John Doe	Jane Doe



- Main hypotheses:
 - Both $A_{\text{self}} > .5$ and $A_{\text{favoriteOther}} > .5$
 - Significant correlation of and A_{self} and the NLT score



Study 3: Convergent Validity

(Meissner & Rothermund, unpublished)

Parameter	Mean Estimate	SE
Re	.28*	.04
A_{self}	.55*	.02
$A_{favoriteOther}$.53 [†]	.02
L_{self}	.66***	.02
$L_{favoriteOther}$.63***	.02
L_{good}	.51***	.03
L_{bad}	.59***	.03



Convergent Validity of A_{self} :

$$r = .25^*$$

Note: median $G^2(6) = 7.09$, $p = .313$

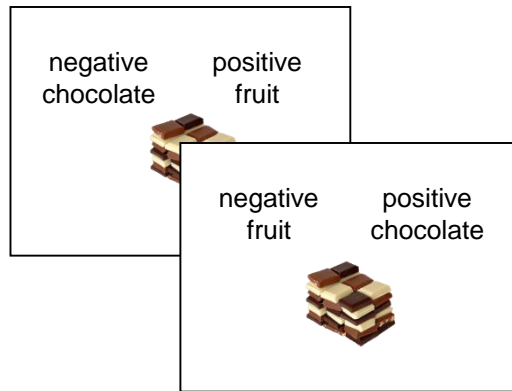
[†] $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$.



Study 4: Predictive Validity

(Meissner & Rothermund, 2013)

- $N = 85$
- fruit-chocolate IAT and consumption behavior
(amount of chocolate eaten while watching a short movie clip)



$\rightarrow A_{\text{chocolate}}$ $r = .24^*$ \rightarrow



Model Validation: Summary

(Meissner & Rothermund, 2013; Meissner & Rothermund, unpublished)

Associations

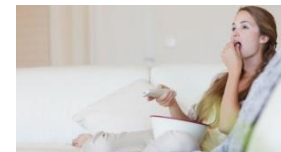
- Reflect the direction and the strength of spontaneous evaluations
- In different attitude domains...



- Convergent



and predictive validity



(outperforming the IAT score)

Model Validation: Summary

(Meissner & Rothermund, 2013)

Label-based identification of the response

- reflects the difficulty of the categorization task
(using pictures vs. words as stimuli)
- depends on cognitive resources
(different response deadlines)

Recoding

- Is reduced if recoding strategies are minimized
(Single-Block IAT, IAT Recoding-Free)
- Correlates with a marker of recoding processes
(the switch-cost effect in the IAT)



Model Validation: Summary

- ✔ Model Fit
- ✔ Parameters respond to relevant manipulations
- ✔ Parameters correlate with relevant criteria



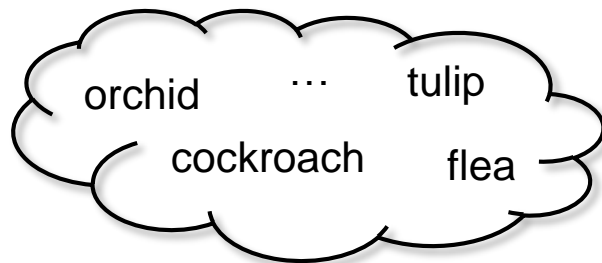
2.3 Model Application

- Study 5: Modality Effects
- Study 6: Insect-Nonword IAT

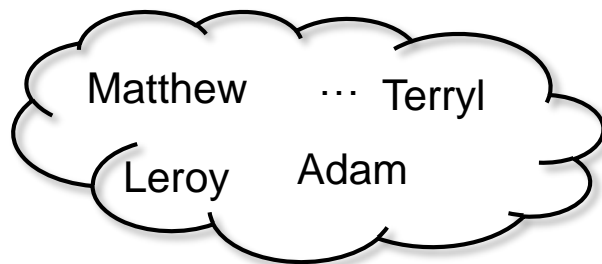


Study 5: Modality Effects

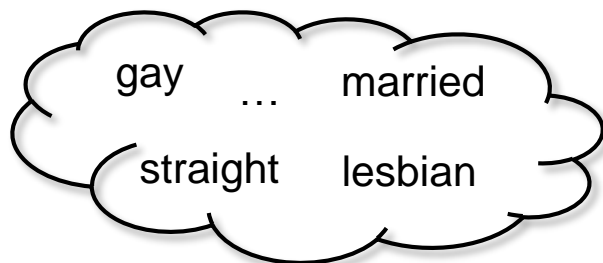
(Meissner & Rothermund, 2015a)



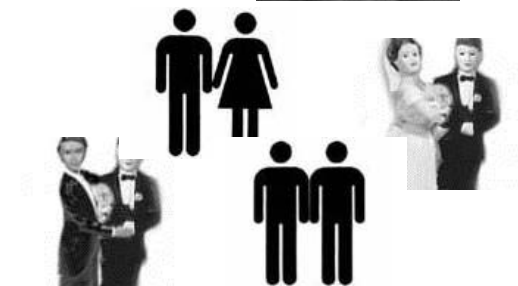
flower-insect IAT



Black-White IAT



sexuality IAT



Study 5: Modality Effects

(Meissner & Rothermund, 2015a)

- Pictorial targets produce **smaller** IAT scores than verbal targets.

(e.g., Chang & Mitchell, 2011; Foroni & Bel-Bahar, 2010; Nosek, Banaji, & Greenwald, 2002)



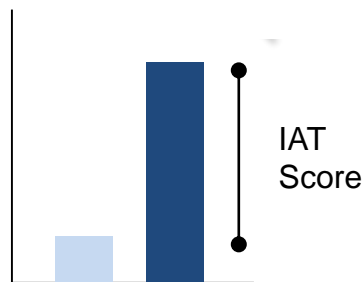
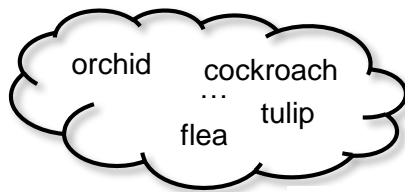
Pictures activate **less extreme attitudes** than words???



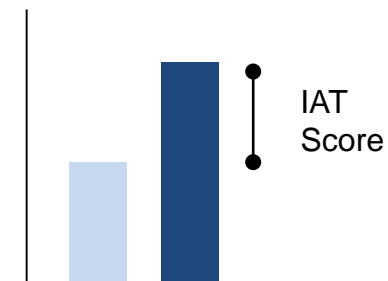
Recoding & Modality Effects

(Meissner & Rothermund, 2015a)

Verbal Targets



Pictorial Targets



Recoding & Modality Effects

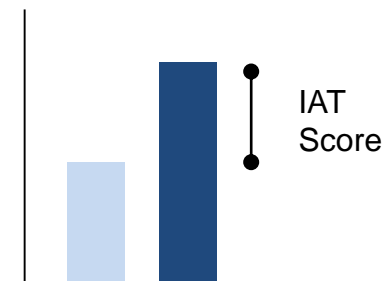
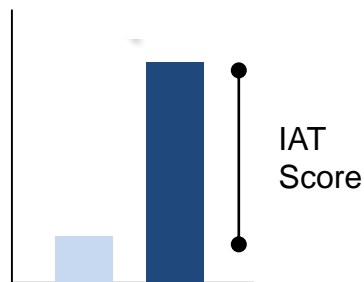
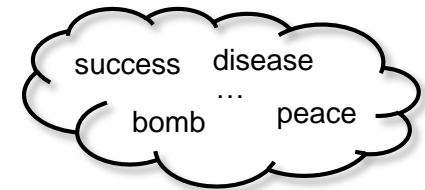
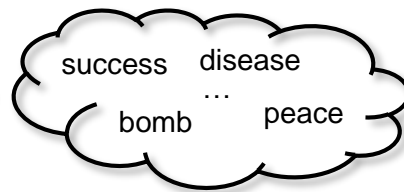
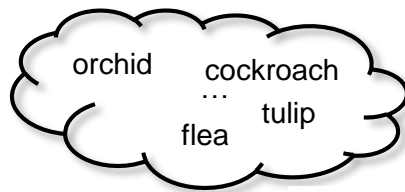
(Meissner & Rothermund, 2015a)

Verbal Targets



Confound

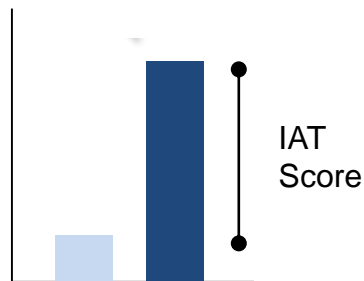
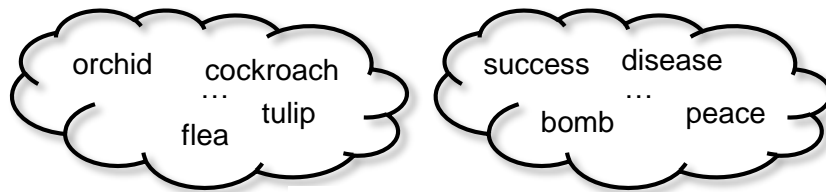
Pictorial Targets



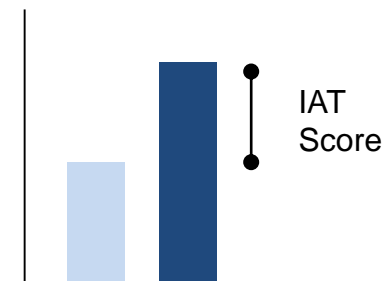
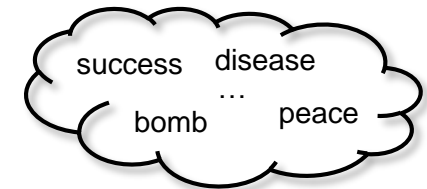
Recoding & Modality Effects

(Meissner & Rothermund, 2015a)

Modality Match Verbal Targets



Modality Mismatch Pictorial Targets

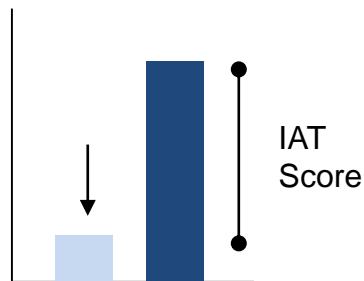
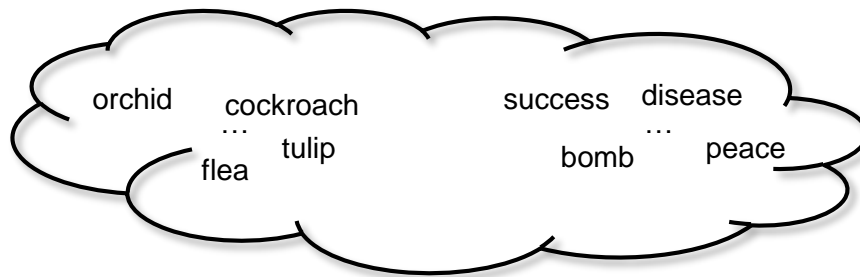


Recoding & Modality Match Effects

(Meissner & Rothermund, 2015a)

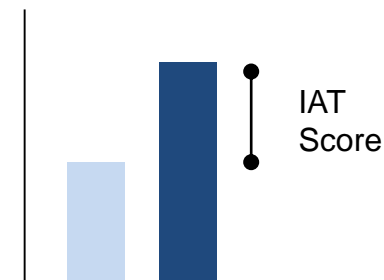
Modality Match

Verbal Targets



Modality Mismatch

Pictorial Targets

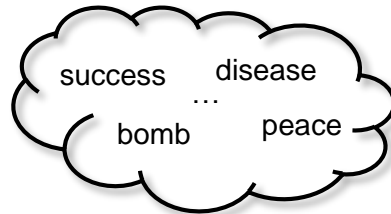
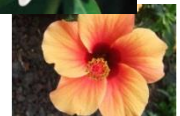
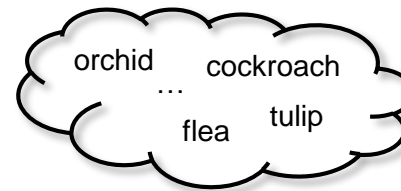


Study 5: Modality Effects

(Meissner & Rothermund, 2015a)

- flower-insect IAT
($N = 80$)

Target Modality *between-subjects*

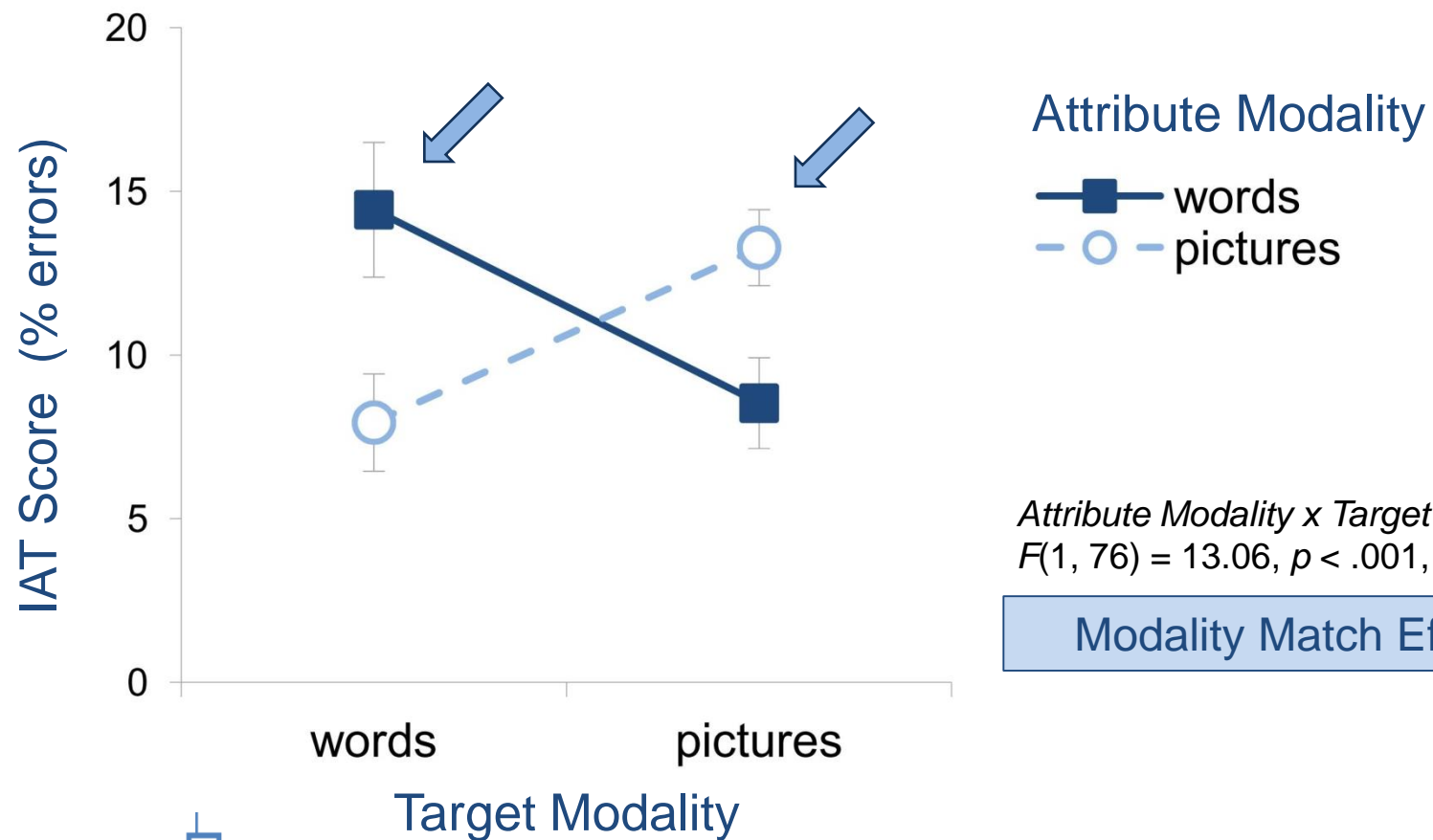
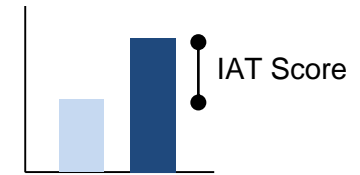


Attribute Modality *between-subjects*

Match	Mismatch
Mismatch	Match

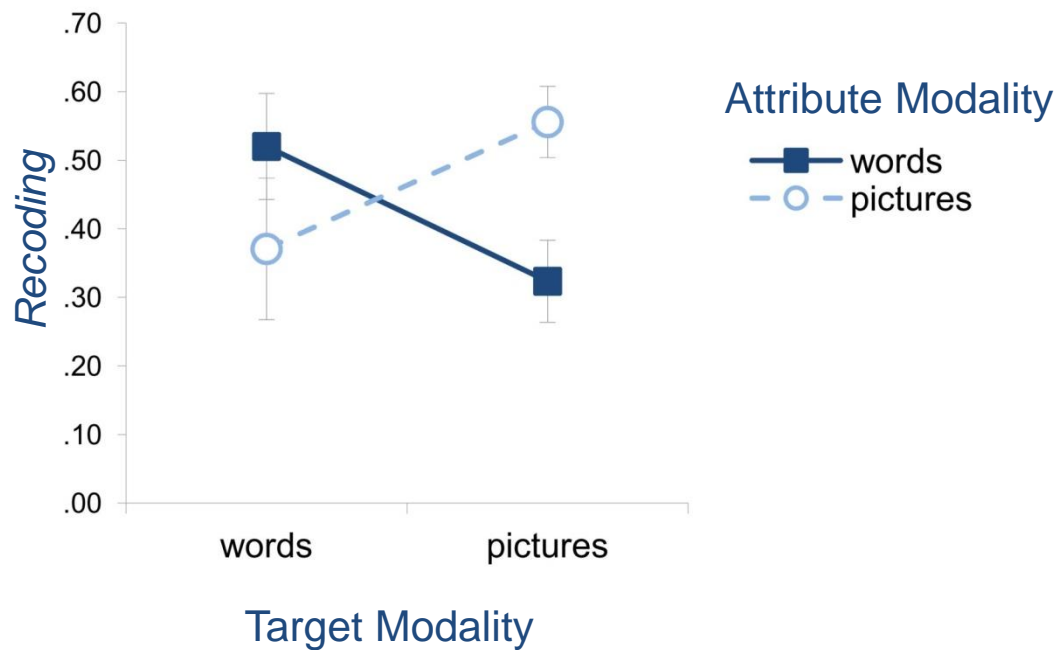
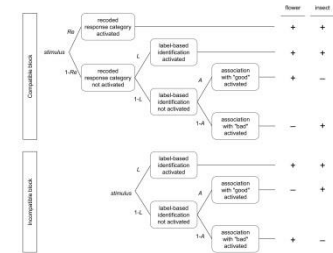
Study 5: Modality Effects

(Meissner & Rothermund, 2015a)



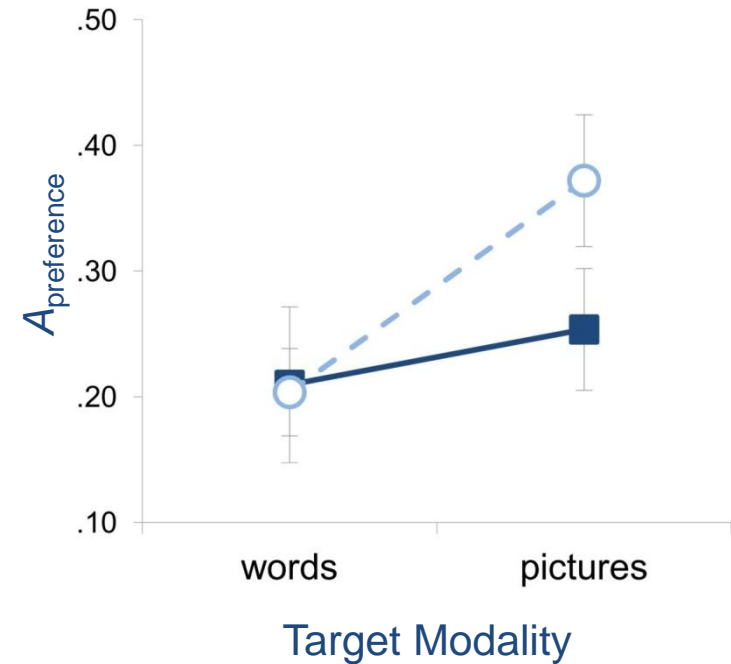
Study 5: Modality Effects

(Meissner & Rothermund, 2015a)



Modality Match Effect

$$F(1, 76) = 6.35, p = .014, \eta_p^2 = .08$$



$$F(1, 76) = 1.52, p = .221, \eta_p^2 = .02$$

$$HE \text{ Target Modality}, F(1, 76) = 4.45, p = .038, \eta_p^2 = .06$$

Study 5: Modality Effects

(Meissner & Rothermund, 2015a)



$$\text{IAT score}_{\text{pictures}} < \text{IAT score}_{\text{words}}$$

- The *modality effect* is actually a **modality match effect**
- ... and can be attributed to **recoding processes** rather than associations.



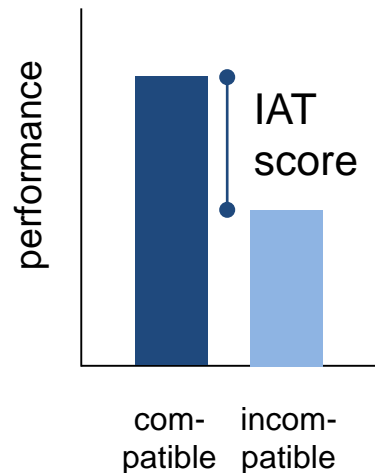
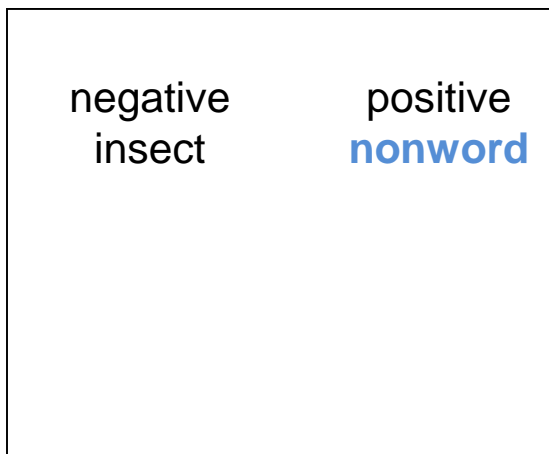
- The associative preference is **even larger for pictorial** compared to verbal targets!



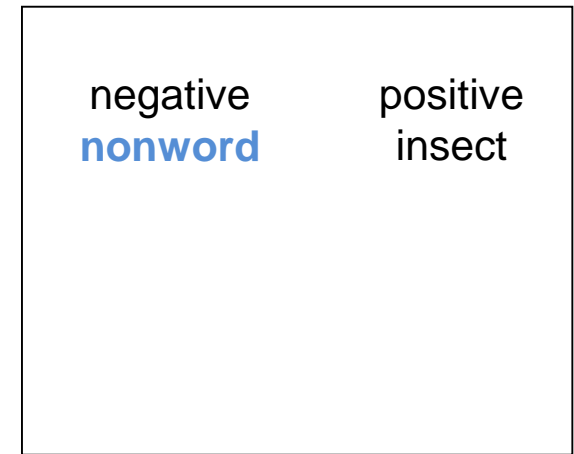
Study 6: Insect-Nonword IAT

(Meissner & Rothermund, 2015b; cf. Brendl, Markman, & Messner, 2001)

Compatible Block



Incompatible Block



Insects are preferred over neutral nonwords?

Task recoding in the incompatible block?

(Chang & Mitchell, 2011; Rothermund & Wentura, 2004)



Study 6: Insect-Nonword IAT

(Meissner & Rothermund, 2015b)

- ReAL model analyses revealed that...
 - The task was recoded in the **incompatible** block.
 $Re > 0$, $\Delta G^2(1) = 9.54$, $p = .002$
 - Nonwords were **neutral**.
 $A_{\text{nonword}} = .5$, $\Delta G^2(1) = 2.73$, $p = .098$
 - Insects actually triggered **negative** associations.
 $A_{\text{insect}} < .5$, $\Delta G^2(1) = 23.61$, $p < .001$



Model Application: Summary

- The IAT score is **not** a pure measure of evaluative associations. Task recoding is an important confound.
- Using the **ReAL Model** as an analysis tool provides insights that could not have been uncovered with traditional scoring procedures.

However, there is more than
just one MPT model for the IAT!



3. Different models for different research questions

Forget about recoding, just for a minute.



The Quad Model

(Conrey, Sherman, Gawronski, Hugenberg, & Groom, 2005)

- Consider this example:

**Black-White IAT scores
increase with age.**

Older adults are more
prejudiced.

No, attitudes remain stable.
It is only the capacity to *inhibit*
those attitudes that decreases
over the lifespan.

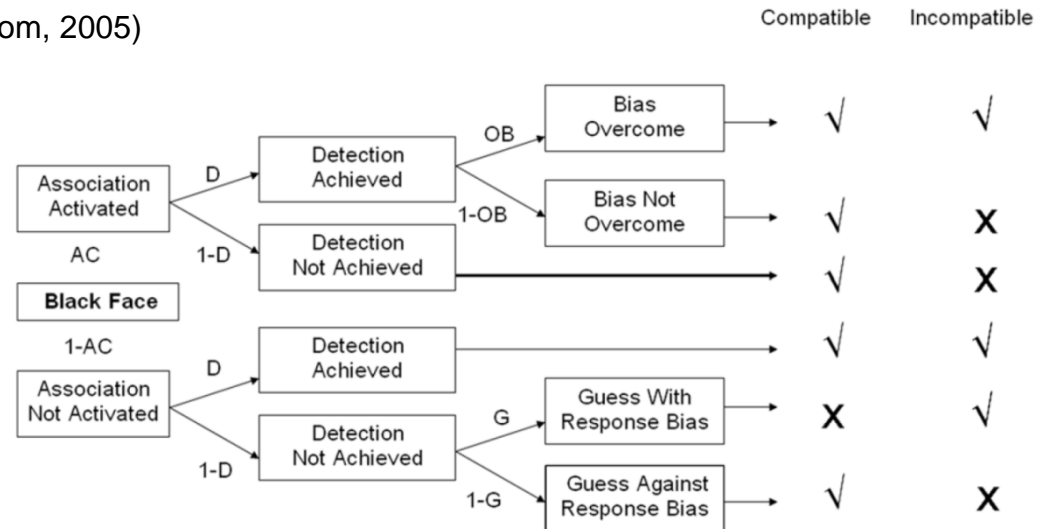
(Gonsalkorale, Sherman, & Klauer, 2009)



The Quad Model

(Conrey, Sherman, Gawronski, Hugenberg, & Groom, 2005)

- The Quad Model disentangles the **activation** and the **inhibition** of attitudes.



- Model parameters

AC Activation of associations ($AC_{\text{flower/pos}}$, $AC_{\text{insect/neg}}$)

OB Overcoming bias (= inhibition)

D Detecting the correct response

G Guessing

Quad vs. ReAL Model

- Both can be applied to IAT data.
- Both claim to reflect the processes involved in the IAT.
- But they differ considerably with regard to parameters and model structure.

➡ How to decide?

- Research interest
- Model fit and complexity (AIC,BIC,FIA...)
- Parameter validity



Quad vs. ReAL Model

Research Interest

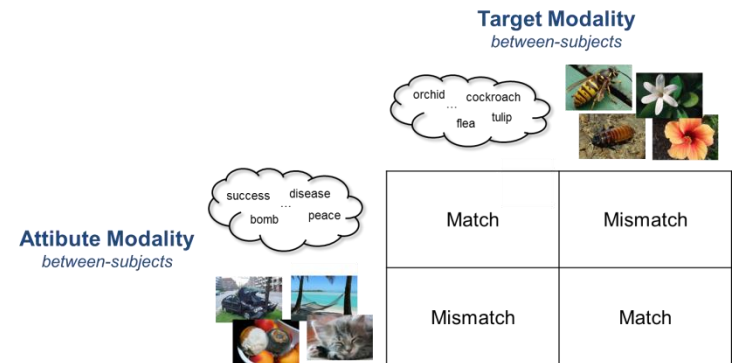
- ... have different objectives and strengths.
- Quad Model
 - Dissociates activation & inhibition of associations
- ReAL Model
 - Dissociates associations & recoding
 - Measures associations even if both attitude objects are evaluated equally



= 0

Quad vs. ReAL Model

Model Fit and Model Complexity



	ReAL	Quad
ΔAIC	-3.69 ✓	0.65 ✗
ΔBIC	-26.30 ✓	-6.89 ✓
cFIA	11.47	9.31
FIA	159.56	166.44

	ReAL	Quad
% participants with $\Delta AIC < 0$	75%	43%
% participants with $\Delta BIC < 0$	100%	89%

$FIA_{ReAL} < FIA_{Quad}$, not only overall but actually for 89% of the participants.

Note. Due to the estimation approach (individual analysis), these are median values for the full sample of 80 participants. For each participant, we sampled 320 trials. The lower-bound trial number for an application of FIA to these data is smaller (lower-bound $N = 112$; see Heck, Moshagen, & Erdfelder, 2014).

Use Excel-Sheet!

The ReAL model is more complex. Still, it provides the better trade-off between fit & complexity.

Quad vs. ReAL Model

Parameter Validity

- The correspondence between Quad and ReAL model parameters is not trivial.

Quad	ReAL
<i>AC</i>	<i>A?</i>
<i>OB</i>	<i>???</i>
<i>D</i>	<i>L?</i>
<i>G</i>	<i>???</i>

And what about *Re*?

- The association parameters of the Quad model (*AC*) could be distorted by recoding.

➡ But are they?



Quad Model – Reanalysis

(cf. Meissner & Rothermund, 2015a)

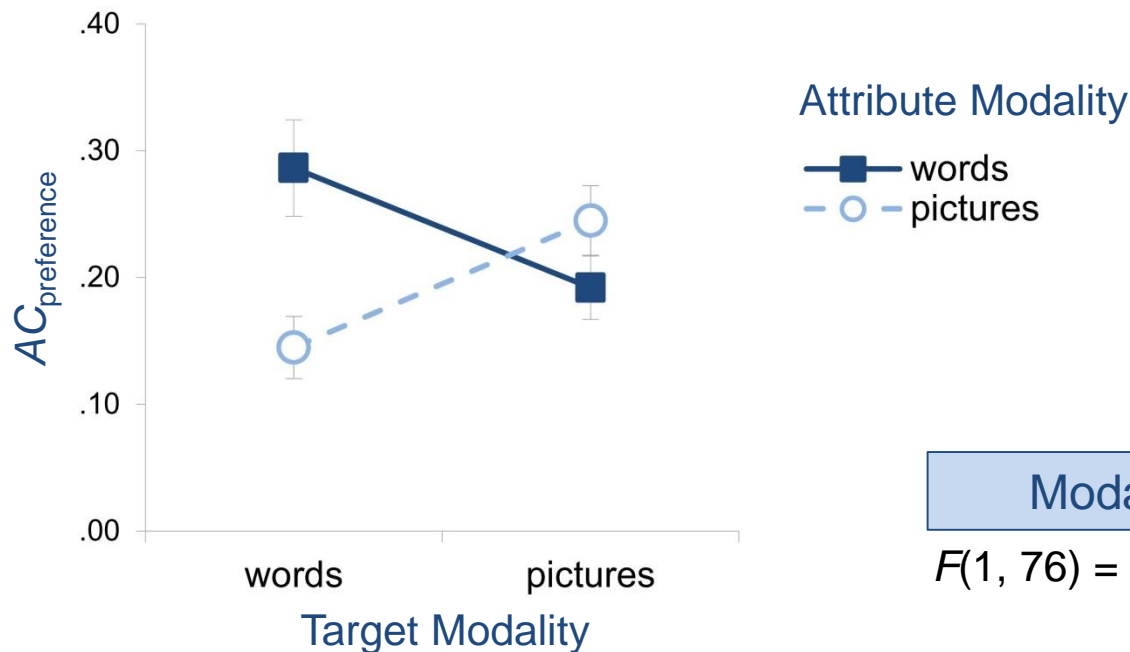
Attribute Modality
between-subjects



Target Modality
between-subjects



Match	Mismatch
Mismatch	Match



Modality Match Effect

$$F(1, 76) = 11.10, p = .001, \eta_p^2 = .13$$

➡ So, yes, they are.

Quad Model – Reanalysis

- What about **convergent validity**?

(Meissner & Rothermund, unpublished)

- ReAL Model (A): $r = .25^*$
- Quad Model (AC): $r = .09$



- ... and **predictive validity**?

(Meissner & Rothermund, 2013)

- ReAL Model (A): $r = .24^*$
- Quad Model (AC): $r = .19^\dagger$



Quad vs. ReAL Model

- Although both Quad and ReAL model fit IAT data,
...FIA suggests to prefer the ReAL model, and
...Quad parameters probably suffer from distortions due to recoding.

Well then, the ReAL model = the real model?

- No. At least, not yet. ReAL model parameters might be distorted as well (e.g., due to inhibition). We are planning more studies to provide a fair model comparison.

And until then?

- Both models have their strengths. So, a model should be chosen depending on the researchers' main interest.



Discussion

*Re*lated ideas?

*A*ny questions?

*L*argely confused?

Thank you.



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